

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**

TITLE OF THE INVENTION

5 SEMICONDUCTOR LASER DEVICE AND SEMICONDUCTOR LASER
MODULE

FIELD OF THE INVENTION

10 The present invention relates to a semiconductor laser device having a greatly
stabilized oscillation wavelength to output a high output laser beam and a
semiconductor laser module.

BACKGROUND OF THE INVENTION

15 A demand for increasing the capacity of optical communication networks has
been recently heightened because of a proliferation of various multimedia including
Internet-delivered multimedia. Responsive to the demand, a WDM (Wavelength
Division Multiplexing) communication system has been used. The WDM
communication system is a system for performing transmission by using a plurality of
wavelengths in a 1,550-nm band. The WDM communication system realizes a
20 remarkable increase of the transmission capacity of a network because optical signals
having a plurality of different wavelengths are simultaneously transmitted through one
optical fiber and thereby it is unnecessary to construct a new line.

25 In the case of the light source, or the amplifying light source, of the optical
signal, it is desired to accurately control the oscillation wavelength and operate a
semiconductor laser element at a high optical output by preventing the thermal
saturation of the element. Conventional semiconductor laser devices prevent an
oscillation wavelength from becoming unstable, and a semiconductor laser element
for outputting a laser beam from being thermally saturated, by setting a thermistor for
measuring the temperature of the semiconductor laser element nearby the
30 semiconductor laser element and controlling the temperature of the semiconductor
laser element by a temperature controlling element such as a Peltier element.

Fig. 15 is a perspective view of a schematic configuration of a conventional

semiconductor laser device. In the case of the semiconductor laser device in Fig. 15, a submount 102 formed by AlN having an insulating characteristic and a high heat conductivity is formed on a carrier 101 formed by CuW and a semiconductor laser element 103 for outputting a laser beam L100 having a predetermined wavelength is 5 formed on the submount 102. A submount 104 formed by AlN is formed on the carrier 101 and a thermistor 105 for measuring the temperature of a semiconductor laser element is formed on the submount 104.

10 The semiconductor laser element 103 and the submount 102 are joined through a metallic thin film 102a. The metallic thin film 102a is metallized with Ti, Pt, and Au at film thicknesses of 60, 200, and 600 nm in order and the semiconductor laser element 103 and submount 102 are joined to each other by a solder material made of AuSn or the like metallized on the Au film. Moreover, the thermistor 105 and submount 104 are joined each other similarly through the metallic thin film 104a.

15 In the case of the semiconductor laser element 103, the face to be joined with the submount 102 serves as a p-side electrode and the upper face serves as an n-side electrode and an active layer for mainly generating heat is set nearby the submount 102. A negative electrode is led to the n-side electrode by an Au wire 106a and the p-side electrode is led to the positive side carrier 101 through the metallic thin film 102a and an Au wire 106b.

20 Referring to Figure 16, the submount 102 secures the insulation of the semiconductor laser element 103 and functions as a heat sink of the semiconductor laser element 103 and is joined to a CuW base 106 to be joined to the bottom of the carrier 101 by AuSn solder, and a Peltier module 107 set to the bottom of the base controls the temperature of the semiconductor laser element 103 in accordance with 25 the temperature detected by the thermistor 105.

Moreover, the thermistor 105 is also insulated from the carrier 101 by the submount 104 similarly to the case of the semiconductor laser element 103 to detect the temperature of the semiconductor laser element 103 through the submount 102, carrier 101, and submount 104 respectively having a high heat conductivity.

30 When performing long distance optical transmission by using the above WDM communication system, it is desireable to increase the output of a laser beam of a signal light source in order to increase the interval between repeaters. Moreover, to

improve the amplification capacity of an optical fiber amplifier, it is desirable to increase the output of a semiconductor laser device used for an exciting light source.

To meet the above demands, a conventional embodiment has a semiconductor laser element for oscillating and outputting a laser beam of 250 mW or more as a laser beam for Erbium doped fiber amplifier (EDFA) excitation. However, a conventional semiconductor laser device using the above high output semiconductor laser element has a problem in that the optical output and service life of the semiconductor laser element are deteriorated.

Fig. 16 shows a front view of the above conventional semiconductor laser device including the above described base and Peltier module. The submounts 102 and 104 are separately provided for the semiconductor laser element 103 and the thermistor 105. The heat generated in the semiconductor laser element 103 is conducted to the thermistor 105 through the metallic thin film 102a, submount 102, metallic thin film 102b, carrier 101, metallic thin film 104b, submount 104, and metallic thin film 104a in order as shown by the arrow YA in Fig. 16. As recognized by the present inventors, because the heat conducting distance is physically increased as described above, detection of the actual temperature of the semiconductor laser element 103 is delayed.

Moreover, because the total of four junction faces corresponding to the metallic thin films 102a, 102b, 104b, and 104a are present on the heat conducting path between the semiconductor laser element 103 and the thermistor 105, heat resistances are generated on these junction faces and thereby, the temperature of the semiconductor laser element 103 is not accurately transferred to the thermistor 105. That is, the thermistor 105 detects a lower temperature having a large difference from the actual temperature of the semiconductor laser element 103 and therefore, the accuracy of a detected temperature is deteriorated. As a result, the temperature control of the semiconductor laser element 103 performed in accordance with the temperature detected by the thermistor 105 is delayed and because the temperature control at a low accuracy is inevitably performed, the oscillation wavelength of the semiconductor laser element 103 becomes unstable and the optical output and service life of the semiconductor laser element 103 are deteriorated.

Moreover, as shown by the arrow YB in Fig. 16, because the total of four

*a¹
conced*

junction faces such as two junction faces corresponding to the metallic thin films 102a and 102b, the junction face between the carrier 101 and the base 106, and the junction face between the base 106 and the Peltier module 107 are present on the heat conducting path between the semiconductor laser element 103 and the Peltier module 107, the heating action or cooling action by the Peltier module 107 is deteriorated whenever passing through these junction faces and resultantly, the temperature control of the semiconductor laser element 103 cannot be quickly or accurately performed.

I think that it is better that next sentence is moved to detailed description. How about do you think?

10 Moreover, when supplying a current of 1A or more to a semiconductor laser element in order to obtain a high optical output and assuming that the total resistance of an Au thin film in the metallic thin film 102a is 0.12Ω , the voltage drop by the Au thin film becomes 0.12 V. Moreover, because the inter-electrode voltage of a semiconductor laser element is approximately 2 V when a current of 1 A is supplied to 15 the semiconductor laser element, the voltage drop of the semiconductor laser element in the resonator length direction becomes un-uniform by 0.12 V. That is, also when considering a current injection path, current injection into a semiconductor laser element becomes ununiform because of passing through a metallic thin film and resultantly, the light density in the active layer becomes ununiform and it is estimated 20 to accelerate the deterioration of the optical output and service life of the semiconductor laser element.

When using a high output semiconductor laser element, it is recognized by the present inventors that it is imprudent to ignore the voltage drop in the metallic thin film between the semiconductor laser element and a submount. If too high, an 25 oscillation wavelength becomes unstable due to the non-uniformity of the voltage drop in the metallic thin film in the resonator length direction. This problem particularly becomes troublesome in the case of a semiconductor laser element designed for a high output operation at a resonator length of 1,000 μm or more.

30 SUMMARY OF THE INVENTION

It is an object of the present invention to address the above-described and other deficiencies of conventional devices and modules.

It is another object of this invention to provide a semiconductor laser device and a semiconductor laser module capable of preventing the optical output and service life of a high output semiconductor laser element from deteriorating. This is achieved by using new materials to reduce the number of interfaces between a laser element and a temperature measuring device, as well as a reduction in the number of interfaces between a laser element and a Peltier module. In addition, performance is enhanced by improving the uniformity of voltage drop of the semiconductor laser element in the resonator length direction by distributing driving currents along a length of the resonator cavity.

10 The first aspect of the present invention includes a semiconductor laser device including a semiconductor laser element for outputting a laser beam, a temperature measuring element for measuring the temperature of the semiconductor laser element, and a carrier having an insulating characteristic and a high heat conductivity, wherein the semiconductor laser element and the temperature measuring element are joined to the carrier through a multi-layer film that includes a gold thin film and are arranged closely to each other such that the heat resistance of a heat conducting path decreases. Within the first aspect, variations in the pattern of the multi-layer film are possible. In addition, the carrier may also include rods of thermally conductive material.

15 20 The second aspect of the present invention includes a semiconductor laser device including a semiconductor laser element for outputting a laser beam, a temperature measuring element for measuring the temperature of the semiconductor laser element, a carrier having an insulating characteristic and a high heat conductivity, and a common laser and temperature measure device submount having a heat conductivity of 500 W/(m · K) or more joined to the carrier through a multi-layer film that includes a gold thin film. The semiconductor laser element and the temperature measuring element are each joined to the common submount via multi-layer film that includes a gold thin film and are arranged closely to each other such that the heat resistance of a heat conducting path decreases.

25 30 The third aspect of the present invention includes a semiconductor laser device including a semiconductor laser element for outputting a laser beam, a temperature measuring element for measuring the temperature of the semiconductor

laser element, an optical monitor for monitoring the output of the laser element, and a carrier having an insulating characteristic and a high heat conductivity, wherein the semiconductor laser element, the temperature measuring element and the optical monitor are joined to the carrier through a multi-layer film that includes a gold thin film and are arranged closely to one another such that the heat resistance of a heat conducting path decreases.

The fourth aspect includes a semiconductor laser device having a semiconductor laser element for outputting a laser beam, a temperature measuring element for measuring the temperature of the semiconductor laser element, a carrier having an insulating characteristic and a high heat conductivity, and laser submount having a heat conductivity of 500 W/(m · K) or more and a joined to the carrier through a multi-layer film that includes a gold thin film. The temperature measuring element is joined directly to the carrier through a multi-layer film that includes a gold thin film and is arranged closely to the semiconductor laser device such that the heat resistance of a heat conducting path decreases. Within the fourth aspect, variations regarding the size and other characteristics of the laser submount are possible.

According to the first through fourth aspects, the heat resistance of the heat conducting path is decreased by using three or less junction faces located on the heat conducting path between the semiconductor laser element and the temperature measuring element and respectively formed by the multi-layer film including the gold thin film.

The fifth aspect of the present invention includes a semiconductor laser module having the semiconductor laser device of any of the above aspects and a temperature controlling element for controlling the temperature of the semiconductor laser element in accordance with the temperature output from the temperature measuring element. In this aspect, the carrier of the semiconductor laser device is joined to the temperature controlling element and the semiconductor laser element is temperature controlled through the carrier.

30 BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and features of this invention will become better understood from the following description with reference to the accompanying drawings.

Figs. 1A to 1C show a configuration of a semiconductor laser device of the first embodiment of the present invention;

Fig. 2 is a graph which shows a difference between the temperature of the semiconductor laser element shown in Fig. 1 and the temperature of a thermistor to 5 the calorific value of the semiconductor laser device;

Fig. 3 is a graph which shows relations between injection currents and output powers of the semiconductor laser element of the semiconductor laser device shown in Fig. 1 and a conventional semiconductor laser element;

Figs. 4A to 4C show a configuration of a semiconductor laser device that is a 10 first modification of the first embodiment of the present invention;

Figs. 5A to 5C show a configuration of a semiconductor laser device that is a second modification of the first embodiment of the present invention;

Figs. 6A to 6C show a configuration of a semiconductor laser device that is a second embodiment of the present invention;

15 Figs. 7A to 7C are graphs which show the experiment data showing the relation between the size and the heat resistance of a diamond submount of the semiconductor laser device which is the second embodiment of the present invention;

Fig. 8 is a perspective view explaining an optimum size of the diamond 20 submount of the semiconductor laser device that is the second embodiment of the present invention;

Figs. 9A and 9B show a configuration of a semiconductor laser device that is third embodiment of the present invention;

Figs. 10A to 10C show a configuration of a semiconductor laser device that is fourth embodiment of the present invention;

25 Fig. 11 shows relations between injection currents and output powers of a semiconductor laser element of the fourth embodiment of the present invention and a conventional semiconductor laser element;

Figs. 12A to 12C show another configuration of the semiconductor laser device that is the fourth embodiment of the present invention;

30 Fig. 13 is a sectional view which shows a configuration of a semiconductor laser module that is fifth embodiment of the present invention;

Fig. 14 is a graph which shows comparison between peak values of output

powers of a conventional semiconductor laser device and the semiconductor laser device described for each of the first and fourth embodiments;

Fig. 15 shows a configuration of a conventional semiconductor laser device; and

5 Fig. 16 is a front view of the semiconductor laser device shown in Fig. 15.

DETAILED DESCRIPTION

Preferred embodiments of a semiconductor laser device and a semiconductor laser module of the present invention are described below by referring to the 10 accompanying drawings.

Fig. 1A is a top view, Fig. 1B is a front view, and Fig. 1C is a right side view of the semiconductor laser device of the first embodiment of the present invention. In Figs. 1A to 1C, a carrier 1 is formed AlN and having an insulating characteristic and a high heat conductivity. A semiconductor laser element 3 outputs a laser beam having 15 a predetermined oscillation wavelength from an end face 3a and is set to this side of a center of an upper portion of the carrier 1 through a metallic thin film 2b. The resonator length of the semiconductor laser element 3 is 1,000 μm or more and the semiconductor laser element 3 outputs a high output laser beam of 250 mW or more. The laser beam output by the semiconductor laser element 3 has an oscillation 20 wavelength of 900 to 1,600 nm in which a 980-nm band and a 1,480-nm band are especially useful in typical communication systems and the 1,480-nm band is particularly useful as an optical fiber amplifier exciting light source such as when used as a pump for a Raman amplifier.

A thermistor 4 is set on the carrier 1 through a metallic thin film 2c, which 25 monitors the temperature of the semiconductor laser element 3. Other metallic thin films 2a and 2d are formed on the carrier 1, patterned, and insulated from each other. The metallic thin film 2b is formed by three layers of Ti, Pt, and Au from the carrier-1 side and the three layers have thicknesses of 60, 200, and 5,000 nm. That is, in contrast to the Au film of the metallic thin film 102a shown in Fig. 15 which has a 30 thickness of 600 nm; the Au film of the metallic thin film 2b has a thickness of 5,000 nm. Thickness of at least, 1,000 nm, 2,000 nm, 3,000 nm, 4,000 nm may be used as well with increasing degrees of performance and aging improvement. However, 5,000

14
13
12
11
10
9
8
7
6
5
4
3
2
1

nm is preferred. Other metallic thin films 2a, 2c and 2d are formed simultaneously with the metallic thin film 2b and have the same film configuration. The semiconductor laser element 3 is joined with the metallic thin film 2b by AuSn solder through a Pt barrier layer.

5 In the case of the semiconductor laser element 3, the p-side electrode at the active layer-3b side is joined correspondingly to the carrier 1, and the n-side electrode is the upper face. The n-side electrode of the semiconductor laser element 3 and the metallic thin film 2a are electrically joined to each other by an Au wire 5. Therefore, the metallic thin film 2a serves as the negative electrode of the semiconductor laser element 3 and the metallic thin film 2b serves as the positive electrode of the semiconductor laser element 3.

The n-side electrode of the semiconductor laser element 3 and the metallic thin film 2a are connected to each other by a plurality of wires 5 so that a current carrying sectional area increases. Moreover, junction points of the wires 5 are arranged at almost equal intervals to disperse power and make the current distribution more uniform. By forming the above spatial wiring by a plurality of wires 5, a resistance value and a voltage drop decrease and thereby, generation of heat decreases, a power ratio only used for laser beam output is increased, and a power light conversion efficiency is improved.

Moreover, by setting thicknesses of Au films of the metallic thin films 2a to 2d to 5,000 nm or more, resistances of the metallic thin films 2a to 2d are decreased, voltage drops are decreased, and a power light conversion efficiency is improved conjointly with the function and advantage of the above wires 5. Moreover, when a large current is injected into the p-side electrode of the semiconductor laser element 3, it is possible to decrease the non-uniformity of voltage drops in the resonator length direction of the semiconductor laser element 3 and resultantly prevent the optical output and service life of the semiconductor laser element 3 from deteriorating.

In this case, it is preferable to make the width W_2 of the metallic thin film 2b almost equal to the width of the metallic thin film 2a. This is because the synthetic resistance value of the metallic thin films 2a and 2b is minimized when making the width W_2 of the metallic thin film 2b almost equal to the width of the metallic thin film 2a. Moreover, the width W_1 between the metallic thin films 2a and 2b is set to a

value at which the insulation between the metallic thin films 2a and 2b can be secured.

Bonding portions of the above wires 5 are linearly arranged in the longitudinal direction of the semiconductor laser element 3 as shown in Fig. 1. However, it is also allowed to uniformly disperse the bonding portions. In this case, it is allowed to use positions shifted from the position of the active layer 3a of the semiconductor laser element 3 as bonding portions. In short, it is an objective for the currents to be uniformly distributed on the upper face of the semiconductor laser element 3 through the wires 5. Thus, as an alternative to the wires 5, a conductive film or foil could be used.

10 The resistance of the thermistor 4 is detected by joining the bottom face of the thermistor 4 to the metallic thin film 2c and joining the upper face of the thermistor 4 to the metallic thin film 2d by a wire as illustrated and the temperature is detected by the resistance value. The thermistor 4 is set nearby the end face 3a from which a laser beam of the semiconductor laser element 3 is emitted. The end face 3a of the semiconductor laser element 3 is made almost flush with an end face of the carrier 1 so that other member does not interfere with a laser beam, otherwise the heat 15 generated nearby the end face 3a of the semiconductor laser element 3 increases.

The carrier 1 functions as a heat sink for the semiconductor laser element 3, the whole bottom face of the carrier 1 is joined to a CuW base 27 (Fig. 13) by AuSn solder 6, and the base 27 is joined to a Peltier module 28 (Fig. 13) for controlling the temperature of the semiconductor laser element 3. The Peltier module 28 prevents the semiconductor laser element 3 from being thermally saturated and the optical output and service life of the semiconductor laser element from deteriorating by mainly performing cooling correspondingly to the temperature detected by the thermistor 14 and controlling the temperature of the semiconductor laser element 3.

In the case of the semiconductor laser device of the first embodiment, the submount 102 shown in Fig. 15 (a conventional device) is not set between the semiconductor laser element 3 and the carrier 1 or the insulating submount 104 shown in Fig. 15 is not set between the thermistor 4 and the carrier 1. Thus, the heat conducting path between the semiconductor laser element 3 and the thermistor 4 is decreased in length at least by the thicknesses of the submounts 102 and 104 compared to the case of the conventional semiconductor laser device shown in Fig.

15. Thereby, the thermistor 4 can quickly detect the temperature of the semiconductor laser element 3 compared to the conventional case, and temperature control could be performed more rapidly.

Moreover, because the submounts 102 and 104 are excluded, two junction faces corresponding to the metallic thin films 2b and 2c are present on the heat conducting path between the semiconductor laser element 3 and the thermistor 4 the above number of junction faces is smaller than the number of junction faces (four faces) present in the conventional semiconductor laser device shown in Fig. 15. That is, in the case of the semiconductor laser device shown in Fig. 1, the heat loss is reduced at least by a value equivalent to the reduced number of junction faces compared to the conventional case and the thermistor 4 can detect a temperature closer to the actual temperature of the semiconductor laser element 3.

Moreover, because the submount 102 is excluded, the total of three junction faces such as two junction faces corresponding to the metallic thin film 2b, the junction face between the carrier 1 and the above base 27, and the junction face between the base 27 and the Peltier module 28 are present on the heat conducting path between the semiconductor laser element 3 and the Peltier module 28. This number is smaller than the case of the conventional semiconductor laser device described for Fig. 16 by one face. That is, it is possible to perform the temperature control of the semiconductor laser element 3 by the Peltier module 28 more quickly and accurately than ever in the conventional device of Fig. 15.

For example, Fig. 2 is a graph which shows the relation of the temperature difference between the semiconductor laser element 3 and the thermistor 4 to the heat generated by the semiconductor laser element 3. In Fig. 2, values shown by a symbol “□” show the relation of the temperature difference between the semiconductor laser element 3 and the thermistor 4. Values shown by a symbol “△” show the relation of the temperature difference between the semiconductor laser element 3 and the thermistor 4 in the conventional semiconductor laser device having submounts 102 and 104 formed by AlN as shown in Fig. 15.

As shown in Fig. 2, it is found that a structure in which the semiconductor laser element 3 and thermistor 4 are set on the carrier 1 has a smaller temperature difference and the difference increases as a calorific value increases. For example,

when an element calorific value is 1.0 [W], the configuration of the first embodiment and the configuration of the conventional example shown in Fig. 15 have almost the same temperature difference of 7°C. However, when the element calorific value is 3.5 [W], the temperature difference is 22.5°C in the case of the first embodiment and 5 25°C in the case of the conventional example and thus, a difference of 2.5°C occurs. Therefore, when a semiconductor laser element for outputting a high output laser beam of 250 W or more is mounted, it is possible to detect a temperature closer to the temperature of the semiconductor laser element 3 and perform more accurate temperature control by using the structure of the semiconductor laser device shown in 10 Fig. 1. As a result, it is possible to always control the semiconductor laser element 3 in a predetermined temperature range and prevent the optical output and service life of the semiconductor laser element 3 from deteriorating.

Fig. 3 is a graph which shows relations between injection current and output power of the semiconductor laser element 3 of the first embodiment and a 15 conventional semiconductor laser element. In Fig. 3, the continuous line A shows the characteristic of the semiconductor laser element 3 of this first embodiment and the broken line shows the characteristic of the semiconductor laser element 103 of the conventional semiconductor laser device shown in Fig. 15. As shown in Fig. 3, the rate of the output power increased in accordance with the increase of injection current 20 in the case of the semiconductor laser element 3 of this first embodiment is larger than the case of the conventional semiconductor laser element 103. Particularly, a difference is not found between output powers between the two up to approximately 200 mA of injection current. However, at approximately 1,500 mA of injection current, the output power of the conventional semiconductor laser element 103 is 25 approximately 360 mW while the output power of the semiconductor laser element 3 of this first embodiment rises up to approximately 410 mW.

The above result that output power increases at the same injection current the corroborates result shown in Fig. 2, that is, the result that the thermistor 4 of the first embodiment can detect the temperature of the semiconductor laser element 3 more 30 accurately than with the conventional device. In other words, because the above Peltier module 28 performs temperature control such as cooling in accordance with a temperature measurement result of the thermistor 4, when the temperature

measurement result is accurate, it is possible to completely cool the semiconductor laser element 3 and finally increase the output power of the semiconductor laser element 3.

The structure of the semiconductor laser device of this first embodiment uses 5 the metallic thin film 2a as the conductor pattern of the n-side electrode in order to shorten wirings of the wires 5 in the above description. However, it is also allowed to use the metallic thin film 2a as the conductor pattern of the p-side electrode and the metallic thin film 2b as the conductor pattern of the n-side electrode. That is, as 10 shown in Fig. 4, an alternative is to use metallic thin film 2a as the conductor pattern of the p-side electrode, set the lead portion to the emission side of the semiconductor laser element 3, and use the metallic thin film 2b as the conductor pattern of the n-side electrode so as to be connected with the n-side electrode of the semiconductor laser element 3 by a wire 5A.

Moreover, as shown in Fig. 5, through use of conductor rods 1a embedded in 15 the carrier 1 it is possible to eliminate the lead portion of the conductor pattern of the p-side electrode of the semiconductor laser element 3, to connect the metallic thin film 2b with a metallic thin film at the back of the carrier 1 and to supply power from the bottom side of the semiconductor laser device. Also in this case, the Au film thickness of the metallic thin film 2b is set to 5,000 μm or more so that a voltage drop 20 due to a resistance decreases. Moreover, a plurality of conductor rods 1a are set to the metallic thin film 2b so that the non-uniformity of voltage drops does not occur in the resonator length direction of the semiconductor laser element 3.

As described above, with the first embodiment it is possible to prevent the optical output and service life from deteriorating even for the high output 25 semiconductor laser element 3 because of setting the semiconductor laser element 3 and the thermistor 4 on the same carrier 1 having an insulating characteristic and a high heat conductivity, decreasing the heat conducting distance so that the thermistor 4 more quickly and accurately detects the temperature of the semiconductor laser element 3, and increasing the Au film thickness of the metallic thin film 2b formed 30 between the semiconductor laser element 3 and the carrier 1 so as to decrease the resistance and eliminate the non-uniformity of injection currents in the resonator length direction.

Moreover, in the case of the first embodiment, Au film thicknesses of the metallic thin films 2a to 2d, particularly Au film thicknesses of the metallic thin films 2a and 2b are increased and the semiconductor laser element 3 and the metallic thin film 2a are connected by a plurality of wires 5. Therefore, the resistance up to the p-side and n-side electrodes of the semiconductor laser element 3 is reduced and it is possible to suppress the calorific value of the semiconductor laser device and improve the power heat conversion efficiency.

By increasing Au film thicknesses of the metallic thin films 2a to 2d and using the structure having a plurality of wiring by the wires 5, it is possible to increase the size of the carrier 1 functioning as a heat sink. That is, in the case of a semiconductor laser device having the high output semiconductor laser element 3, it is necessary to increase the size of a heat sink for radiating heat. However, even when the size of the heat sink is increased, it is possible to efficiently perform the function of the semiconductor laser element 3, that is, oscillation of a high output and stable laser beam.

The second embodiment of the present invention is described below. In the case of the above first embodiment, the semiconductor laser element 3 and thermistor 4 are set on the same carrier 1 formed by AlN. In the case of the second embodiment, however, a semiconductor laser element 3 and a thermistor 4 are set on a submount formed by a material, such as diamond, having a heat conductivity five times larger than that of AlN.

Fig 6A is a top view, Fig 6B is a front view, and Fig 6C is a right side view of the semiconductor laser device of the second embodiment of the present invention. In Figs. 6A to 6C, a carrier 13 is formed by AlN having an insulating characteristic and a high heat conductivity and a diamond submount 11 is set on the center of the upper portion through a metallic thin film 12. Configurations of the semiconductor laser element 3, thermistor 4, a wire 5, and metallic thin films 2a to 2d are the same as the case of the first embodiment and the same component is provided with the same symbol.

Metallic thin films 12a to 12d corresponding to patterns of the metallic thin films 2a to 2d are formed on portions other than the area in which the diamond submount 11 is set on the carrier 13. These metallic thin films 12a to 12d are

respectively formed by an Au film. That is, the metallic thin films 2a to 2d and the metallic thin films 12a to 12d are respectively bonded by the illustrated wire and each pair realizes a configuration corresponding to each of the metallic thin films 2a to 2d shown in Fig 1.

5 In the case of the second embodiment, the carrier 1 shown for the first embodiment is realized by combining the diamond submount 11 with the carrier 13. However, the total height (thickness) of the diamond submount 11 and the carrier 13 is the same as the height of the carrier 1 of the first embodiment. Thereby, it is possible to make positions of laser beams emitted from the semiconductor laser element 3 the same. Because the carrier 13 is bonded on a CuW base 27 (Fig. 13) in the case of the second embodiment, the AlN carrier 13 is held by the diamond submount 11 and base 27 in order to moderate the strain between the submount 11 and the base 27.

10 Sizes of diamond for realizing effective radiation are described below. Figs. 7A to 7C are graphs which show experiment data showing relations between sizes and 15 heat resistances of the diamond submount 11. Fig. 7A is a graph which shows the relation between thicknesses and heat resistances when fixing the length of the diamond submount 11 to 2.5 mm and the width of the diamond submount to 1.0 mm. Fig. 7B is a graph which shows the relation between thicknesses and heat resistances when fixing the thickness of the diamond submount 11 to 0.2 mm and the width of it to 1.0 mm. Fig. 7C is a graph which shows the relation between widths and heat 20 resistances when fixing the length of the diamond submount 11 to 2.5 mm and the width of it to 0.2 mm. From every graph, it is found that a heat resistance converges to a certain minimum value as a size increases. Therefore, it is possible to estimate an optimum size of the submount at which a heat resistance is minimized.

25 Fig. 8 is a perspective view for explaining an optimum size of the diamond submount 11. As a result of estimating a size at which a heat resistance becomes smaller in accordance with the experiment data shown in Fig. 7 and the cost, the present inventor finds that it is preferable to form a diamond submount 11 at a thickness SH of 0.4 mm, a length SL of 3.2 mm, and a width SW of 3.2 mm. The 30 above experiment data is a result of setting the thickness LH of the semiconductor laser element 3 to 0.13 mm, the length LL of it to 2.0 mm, and the width LW of it to 0.35 mm. For the size of the diamond submount 11, it is also possible to set the

thickness SH to 0.3 mm, the length SL to 2.7 mm, and the width SW to 1.0 mm and use a structure suppressing a heat resistance within a value 1.2 times larger than the above minimum heat resistance.

Thus, a shape of the diamond submount 11 including its thickness is decided
5 so that the heat resistance decreases. Moreover, the diamond submount 11 uses polycrystal diamond synthesized through chemical vapor deposition (CVD). Diamond is a material having a highest heat conductivity, which can further improve the radiation effect of the semiconductor laser element 3.

The whole bottom face of the carrier 13 is joined to the CuW base 27 by
10 AuSn solder 6 and moreover, the base 27 is joined to a Peltier module 28 (Fig. 13) for controlling the temperature of the semiconductor laser element 3. The Peltier module 28 mainly performs cooling in accordance with the temperature detected by the thermistor 4, prevents the semiconductor laser element 3 from being thermally saturated by controlling the temperature of the semiconductor laser element 3, and
15 prevents the optical output and the service life of the semiconductor laser element 3 from deteriorating.

In this case, by setting thicknesses of Au films of the metallic thin films 2a to 2d to 5,000 nm or more, resistances of the metallic thin films 2a to 2d are decreased, voltage drops are decreased, and a power light conversion efficiency is improved.
20 Moreover, when a large current is injected into the p-side electrode of the semiconductor laser element 3, it is possible to reduce the non-uniformity of voltage drops in the resonator length direction of the semiconductor laser element 3 and resultantly prevent the optical output and service life of the semiconductor laser element 3 from deteriorating.

25 Because the semiconductor laser element 3 and thermistor 4 are set on a common diamond submount 11, the heat conducting path between the semiconductor laser element 3 and the thermistor 4 is shortened similar to the case of the first embodiment. Thereby, the thermistor 4 can detect the temperature of the semiconductor laser element 3 more quickly than in the first embodiment.

30 As with the first embodiment, the fact that heat resistance is reduced because of reduction of the number of junction faces, the thermistor 4 can detect a temperature closer to the actual temperature of the semiconductor laser element 3. Also, it is still

possible to perform the temperature control of the semiconductor laser element 3 by the Peltier module 28 (Fig. 13) more quickly and accurately than the conventional semiconductor laser device shown in Fig. 15 because the diamond submount 11 has a heat conductivity higher than that of AlN which is the material of a submount 102 (Fig. 15) in a conventional semiconductor laser device. Moreover, by using the diamond submount 11, it is possible to quickly diffuse the heat generated in the semiconductor laser element 3 particularly in a wide range including the transverse direction and improve the radiation effect compared to the case of a conventional AlN submount. That is, it is possible to suppress a temperature rise to an injection current compared to the case of a semiconductor laser element set to a conventional semiconductor laser device and realize a high output semiconductor laser device by resultantly converting the value equivalent to the reduction of the temperature rise into output power.

As described above, with the second embodiment it is possible to prevent the optical output and service life from deteriorating even for the high output semiconductor laser element 3. This is due to setting the semiconductor laser element 3 and thermistor 4 on the same diamond mount 11 having an insulating characteristic and a high heat conductivity and decreasing the heat conducting distance. With this configuration, the thermistor 4 more quickly and accurately detects the temperature of the semiconductor laser element 3, the resistance is decreased by increasing the Au-film thickness of the metallic thin film 2b formed between the semiconductor laser element 3 and the diamond submount 11, and the non-uniformity of current injection in the resonator length direction is eliminated.

In the case of the above first and second embodiments, the semiconductor laser element 3 and thermistor 4 are set on the same substrate of the AlN carrier 1 or diamond submount 11. However, it is also allowed to use other material for the carrier, such as Si or cubic boron nitride (cBN) polycrystal, having an insulating characteristic and a high heat conductivity in accordance with the thermal expansion coefficient of the semiconductor laser element 3.

The third embodiment of the present invention is described below. In the case of the above first and second embodiments, the semiconductor laser element 3 and thermistor 4 are set on a common carrier 1 or diamond submount 11. In the case

of this third embodiment, however, an optical monitor for monitoring a laser beam output from the semiconductor laser element 3 is further set on the same carrier 1 or diamond submount 11.

Fig 9A is a top view, Fig 9B is a front view, and Fig 9C is a left side view of the semiconductor laser device of the third embodiment of the present invention. In Figs. 9A to 9C, the semiconductor laser device has a semiconductor laser element 3 and a thermistor 4 on a carrier 1 formed by AlN having an insulating characteristic and a high heat conductivity and moreover includes an optical monitor 7 for monitoring a laser beam radiated from the rear side of the semiconductor laser element 3. The optical monitor 7 is realized by a photodiode.

In Figs. 9A to 9C, the carrier 1 is provided with a conductor rod 1a to connect a metallic thin film 2e at the upper portion with AuSn solder 6 at the lower portion by a low resistance. The n-side electrode of the semiconductor laser element 3 is connected to a metallic thin film 2a by a wire 5a while the p-side electrode of the semiconductor laser element 3 is electrically joined with metallic thin films 2b and 2e by a wire 5b and moreover connected to the AuSn solder 6 through the conductor rod 1a and a base 27 (Fig 13).

One electrode of the thermistor 4 is connected to a metallic thin film 2d through a wire 5d and the other electrode is connected to a metallic thin film 2c. One electrode of the optical monitor 7 is connected to a metallic thin film 2f through a wire 5c and the other electrode of it is connected to a metallic thin film 2g. The metallic thin films 2a to 2g are electrically insulated from each other. The metallic thin films 2a to 2g are respectively formed by three layers of Ti, Pt, and Au and have thicknesses of 60, 200, and 5,000 nm.

The bottom face of the carrier 1 is joined to a CuW base 27 by the AuSn solder 6 and the base 27 is joined to a Peltier module 28 (Fig. 13) for controlling the temperature of the semiconductor laser element 3. The Peltier module 28 mainly operates in accordance with the temperature detected by the thermistor 4 and prevents the semiconductor laser element 3 from being thermally saturated and the optical output and service life of the semiconductor laser element 3 from deteriorating by controlling the temperature of the semiconductor laser element 3.

In this case, by setting the thickness of the Au film of the metallic thin film

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
2510
2511
2512
2513
2514
2515
2516
2517
2518
2519
2520
2521
2522
2523
2524
2525
2526
2527
2528
2529
2530
2531
2532
2533
2534
2535
2536
2537
2538
2539
2540
2541
2542
2543
2544
2545
2546
2547
2548
2549
2550
2551
2552
2553
2554
2555
2556
2557
2558
2559
2560
2561
2562
2563
2564
2565
2566
2567
2568
2569
2570
2571
2572
2573
2574
2575
2576
2577
2578
2579
2580
2581
2582
2583
2584
2585
2586
2587
2588
2589
2590
2591
2592
2593
2594
2595
2596
2597
2598
2599
25100
25101
25102
25103
25104
25105
25106
25107
25108
25109
25110
25111
25112
25113
25114
25115
25116
25117
25118
25119
25120
25121
25122
25123
25124
25125
25126
25127
25128
25129
25130
25131
25132
25133
25134
25135
25136
25137
25138
25139
25140
25141
25142
25143
25144
25145
25146
25147
25148
25149
25150
25151
25152
25153
25154
25155
25156
25157
25158
25159
25160
25161
25162
25163
25164
25165
25166
25167
25168
25169
25170
25171
25172
25173
25174
25175
25176
25177
25178
25179
25180
25181
25182
25183
25184
25185
25186
25187
25188
25189
25190
25191
25192
25193
25194
25195
25196
25197
25198
25199
25200
25201
25202
25203
25204
25205
25206
25207
25208
25209
25210
25211
25212
25213
25214
25215
25216
25217
25218
25219
25220
25221
25222
25223
25224
25225
25226
25227
25228
25229
25230
25231
25232
25233
25234
25235
25236
25237
25238
25239
25240
25241
25242
25243
25244
25245
25246
25247
25248
25249
25250
25251
25252
25253
25254
25255
25256
25257
25258
25259
25260
25261
25262
25263
25264
25265
25266
25267
25268
25269
25270
25271
25272
25273
25274
25275
25276
25277
25278
25279
25280
25281
25282
25283
25284
25285
25286
25287
25288
25289
25290
25291
25292
25293
25294
25295
25296
25297
25298
25299
252100
252101
252102
252103
252104
252105
252106
252107
252108
252109
252110
252111
252112
252113
252114
252115
252116
252117
252118
252119
252120
252121
252122
252123
252124
252125
252126
252127
252128
252129
252130
252131
252132
252133
252134
252135
252136
252137
252138
252139
252140
252141
252142
252143
252144
252145
252146
252147
252148
252149
252150
252151
252152
252153
252154
252155
252156
252157
252158
252159
252160
252161
252162
252163
252164
252165
252166
252167
252168
252169
252170
252171
252172
252173
252174
252175
252176
252177
252178
252179
252180
252181
252182
252183
252184
252185
252186
252187
252188
252189
252190
252191
252192
252193
252194
252195
252196
252197
252198
252199
252200
252201
252202
252203
252204
252205
252206
252207
252208
252209
252210
252211
252212
252213
252214
252215
252216
252217
252218
252219
252220
252221
252222
252223
252224
252225
252226
252227
252228
252229
252230
252231
252232
252233
252234
252235
252236
252237
252238
252239
252240
252241
252242
252243
252244
252245
252246
252247
252248
252249
252250
252251
252252
252253
252254
252255
252256
252257
252258
252259
252260
252261
252262
252263
252264
252265
252266
252267
252268
252269
252270
252271
252272
252273
252274
252275
252276
252277
252278
252279
252280
252281
252282
252283
252284
252285
252286
252287
252288
252289
252290
252291
252292
252293
252294
252295
252296
252297
252298
252299
252300
252301
252302
252303
252304
252305
252306
252307
252308
252309
252310
252311
252312
252313
252314
252315
252316
252317
252318
252319
252320
252321
252322
252323
252324
252325
252326
252327
252328
252329
252330
252331
252332
252333
252334
252335
252336
252337
252338
252339
252340
252341
252342
252343
252344
252345
252346
252347
252348
252349
252350
252351
252352
252353
252354
252355
252356
252357
252358
252359
252360
252361
252362
252363
252364
252365
252366
252367
252368
252369
252370
252371
252372
252373
252374
252375
252376
252377
252378
252379
252380
252381
252382
252383
252384
252385
252386
252387
252388
252389
252390
252391
252392
252393
252394
252395
252396
252397
252398
252399
252400
252401
252402
252403
252404
252405
252406
252407
252408
252409
252410
252411
252412
252413
252414
252415
252416
252417
252418
252419
252420
252421
252422
252423
252424
252425
252426
252427
252428
252429
252430
252431
252432
252433
252434
252435
252436
252437
252438
252439
252440
252441
252442
252443
252444
252445
252446
252447
252448
252449
252450
252451
252452
252453
252454
252455
252456
252457
252458
252459
252460
252461
252462
252463
252464
252465
252466
252467
252468
252469
252470
252471
252472
252473
252474
252475
252476
252477
252478
252479
252480
252481
252482
252483
252484
252485
252486
252487
252488
252489
252490
252491
252492
252493
252494
252495
252496
252497
252498
252499
252500
252501
252502
252503
252504
252505
252506
252507
252508
252509
252510
252511
252512
252513
252514
252515
252516
252517
252518
252519
252520
252521
252522
252523
252524
252525
252526
252527
252528
252529
252530
252531
252532
252533
252534
252535
252536
252537
252538
252539
252540
252541
252542
252543
252544
252545
252546
252547
252548
252549
252550
252551
252552
252553
252554
252555
252556
252557
252558
252559
252560
252561
252562
252563
252564
252565
252566
252567
252568
252569
252570
252571
252572
252573
252574
252575
252576
252577
252578
252579
252580
252581
252582
252583
252584
252585
252586
252587
252588
252589
252590
252591
252592
252593
252594
252595
252596
252597
252598
252599
252600
252601
252602
252603
252604
252605
252606
252607
252608
252609
252610
252611
252612
252613
252614
252615
252616
252617
252618
252619
252620
252621
252622
252623
252624
252625
252626
252627
252628
252629
252630
252631
252632
252633
252634
252635
252636
252637
252638
252639
252640
252641
252642
252643
252644
252645
252646
252647
252648
252649
252650
252651
252652
252653
252654
252655
252656
252657
252658
252659
252660
252661
252662
252663
252664
252665
252666
252667
252668
252669
252670
252671
252672
252673
252674
252675
252676
252677
252678
252679
252680
252681
252682
252683
252684
252685
252686
252687
252688
252689
252690
252691
252692
252693
252694
252695
252696
252697
252698
252699
252700
252701
252702
252703
252704
252705
252706
252707
252708
252709
252710
252711
252712
252713
252714
252715
252716
252717
252718
252719
252720
252721
252722
252723
252724
252725
252726
252727
252728
252729
252730
252731
252732
252733
252734
252735
252736
252737
252738
252739
252740
252741
252742
252743
252744
252745
252746
252747
252748
252749
252750
252751
252752
252753
252754
252755
252756
252757
252758
252759
252760
252761
252762
252763
252764
252765
252766
252767
252768
252769
252770
252771
252772
252773
252774
252775
252776
252777
252778
252779
252780
252781
252782
252783
252784
252785
252786
252787
252788
252789
252790
252791
252792
252793
252794
252795
252796
252797
252798
252799
252800
252801
252802
252803
252804
252805
252806
252807
252808
252809
252810
252811
252812
252813
252814
252815
252816
252817
252818
252819
252820
252821
252822
252823
252824
252825
252826
252827
252828
252829
252830
252831
252832
252833
252834
252835
252836
252837
252838
252839
252840
252841
252842
252843
252844
252845
252846
252847
252848
252849
252850
252851
252852
252853
252854
252855
252856
252857
252858
252859
252860
252861
252862
252863
252864
252865
252866
252867
252868
252869
252870
252871
252872
252873
252874
252875
252876
252877
252878
252879
252880
252881
252882
252883
252884
252885
252886
252887
252888
252889
252890
252891
252892
252893
252894
252895
252896
252897
252898
252899
252900
252901
252902
252903
252904
252905
252906
252907
252908
252909
252910
252911
252912
252913
252914
252915
252916
252917
252918
252919
252920
252921
252922
252923
252924
252925
252926
252927
252928
252929
252930
252931
252932
252933
252934
252935
252936
252937
252938
252939
252940
252941
252942
252943
252944
252945
252946
252947
252948
252949
252950
252951
252952
252953
252954
252955
252956
252957
252958
252959
252960
252961
252962
252963
252964
252965
252966
252967
252968
252969
252970
252971
252972
252973
252974
252975
252976
252977
252978
252979
252980
252981
252982
252983
252984
252985
252986
252987
252988
252989
252990
252991
252992
252993
252994
252995
252996
252997
252998
252999
252100
252101
252102
252103
252104
252105
252106
252107
252108
252109
252110
252111
252112
252113
252114
252115
252116
252117
252118
252119
252120
252121
252122
252123
252124
252125
252126
252127
252128
252129
252130
25

2b to 5,000 nm or more, the resistance of the metallic thin film 2b decreases, the voltage drop decreases, and when a large current is injected into the semiconductor laser element 3, it is possible to decrease the non-uniformity of voltage drops in the resonator length direction of the semiconductor laser element 3 and resultantly, the 5 optical output is prevented from deteriorating.

In the third embodiment, the length of the heat conducting path between the semiconductor laser element 3 and thermistor 4 decreases similarly to the case of the first embodiment because the semiconductor laser element 3 and thermistor 4 are set on the carrier 1 without using the submounts 102 and 104 shown in Fig. 15. Thereby, 10 the thermistor 4 can quickly detect the temperature of the semiconductor laser element 3 compared to a conventional thermistor. Moreover, decrease of heat loss due to decrease of the number of junction faces, that is, the fact that the thermistor 4 can detect a temperature closer to the actual temperature of the semiconductor laser element 3 is the same as the case of the first embodiment.

15 An advantage of the third embodiment is that it is possible to downsize the semiconductor laser device by setting the optical monitor on the same carrier 1.

As described above, with the third embodiment it is possible to prevent the optical output from deteriorating even for the high output semiconductor laser element 3 and accelerate downsizing of a semiconductor laser device provided with an optical 20 monitor because the semiconductor laser element 3 and thermistor 4 are set on the same carrier 1 having an insulating characteristic and a high heat conductivity, the optical monitor 7 is further set, the heat conducting distance is decreased, the thermistor 4 more quickly and accurately detects the temperature of the semiconductor laser element 3, and the thickness of the Au film of the metallic thin film 2b formed 25 between the semiconductor laser element 3 and carrier 1 is increased so as to decrease the resistance and eliminate the non-uniformity of current injection in the resonator length direction.

The fourth embodiment of the present invention is described below. In the case of the conventional semiconductor laser device shown in Fig. 15, an AlN 30 submount on which a semiconductor laser element is mounted and an AlN submount on which a thermistor is mounted are set on the same carrier. In the case of the fourth embodiment, however, the thermistor submount is excluded by directly mounting a

thermistor on a carrier similar to the first embodiment and a semiconductor laser element is set on a diamond submount similar to the second embodiment.

Fig. 10A is a top view, Fig. 10B is a front view, and Fig. 10C is a right side view of the fourth embodiment of the present invention. In Figs. 10A to 10C, a carrier 1 is formed by AlN having a high insulating characteristic and a high heat conductivity. As shown in Figs. 10A to 10C, metallic thin films 2a to 2d are patterned and formed on the carrier 1 so as to be insulated from each other. The metallic thin films 2a to 2d are formed as a structure in which Ti, Pt, and Au are layered in order from the carrier-1 side and the layers have thicknesses of 60, 200, and 5,000 nm.

A diamond submount 2 formed by polycrystal diamond is set on the carrier 1 through the metallic thin film 2b. A semiconductor laser element 3 is set on the diamond submount 2 through a metallic thin film 2h similarly to the above metallic thin film. The diamond submount 2 secures the insulation of the semiconductor laser element 3 and functions as a heat sink of the semiconductor laser element 3.

The p-side electrode at the active layer side of the semiconductor laser element 3 is joined so as to face the diamond submount 2 and the n-side electrode is the upper face. The n-side electrode of the semiconductor laser element 3 is electrically connected with the metallic thin film 2a by Au wires 5. The p-side electrode and metallic thin film 2b of the semiconductor laser element 3 are electrically connected to each other through a metallic thin film 2h and an illustrated wire. Therefore, the metallic thin film 2a serves as the negative electrode of the semiconductor laser element 3 and the metallic thin film 2b serves as the positive electrode of the semiconductor laser element 3.

The wires 5 for electrically connecting the n-side electrode with the metallic thin film 2a of the semiconductor laser element 3 are constituted by a plurality of wires so as to increase the current carrying area. Thus, the resistance value generated at a wiring portion decreases and it is possible to reduce the voltage drop at the portion. Reduction of the voltage drop contributes to suppression of heat generation and increase of a power ratio only used for a laser beam output and resultantly improves a power light conversion efficiency. Moreover, by making intervals between connection points of the wires 5 almost equal, it is possible to realize power dispersion. Thereby, it is possible to reduce the non-uniformity of voltage drops and

4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9

resultantly prevent the optical output and service life of the semiconductor laser element 3 from deteriorating.

Bonding portions of the above wires 5 are linearly arranged in the longitudinal direction of the semiconductor laser element 3 as shown in Fig. 10A.

5 However, it is also allowed to uniformly disperse the bonding portions on the surface of the n-side electrode of the semiconductor laser element 3. In this case, it is also possible to set the bonding portions to positions shifted from the position of the active layer of the semiconductor laser element 3. In short, it is preferable that currents are uniformly distributed on the upper face of the semiconductor laser element 3 through 10 the wires 5.

As shown in Figs. 10A to 10C, a thermistor 4 for measuring the temperature of the semiconductor laser element 3 is set on the carrier 1 through the metallic thin film 2c. The lower face of the thermistor 4 serving as one electrode is joined to the metallic thin film 2c and the upper face of it serving as the other electrode is 15 electrically connected with the metallic thin film 2d through the illustrated wire.

By setting the high output semiconductor laser element 3 so that the end face 3a of the semiconductor laser element 3 becomes almost flush with the end face of the carrier 1, it is possible to reduce the interference of a laser beam generated with other member. However, the vicinity of the end face 3a of the semiconductor laser element 20 3 cannot greatly receive the radiation effect by the submount 2 and therefore, the vicinity easily has a high temperature compared to other portion of the semiconductor laser element 3. Therefore, it is particularly preferable to set the thermistor 4 nearby the end face 3a from which a laser beam of the semiconductor laser element 3 is emitted.

25 Since the submount 104 shown in Fig. 15 is not used, the length of the heat conducting path between the semiconductor laser element 3 and the thermistor 4 is decreased by at least the thickness of the excluded submount 104 compared to the case of the conventional semiconductor laser device shown in Fig. 15. Thereby, the thermistor 4 can detect the temperature of the semiconductor laser element 3 more 30 quickly than ever.

In addition, because the submount 104 is excluded, the number of junction faces (three) corresponding to the metallic thin films 2b, 2c, and 2h present on the heat

conducting path between the semiconductor laser element 3 and the thermistor 4 is smaller than the number of junction faces (four) present in the conventional semiconductor laser device shown in Fig. 15. Thus, in the case of the semiconductor laser device shown in Fig. 10, the heat resistance decreases by at least a value 5 equivalent to reduction of the number of junction faces compared to a conventional case and the thermistor 4 can detect a temperature closer to the actual temperature of the semiconductor laser element 3.

It is possible to control the temperature of the semiconductor laser element 3 by the Peltier module 28 (Fig. 13) more quickly and accurately than in the 10 conventional case because the diamond submount 2 has a heat conductivity higher than that of AlN which is the material of the conventional submount 102 shown in Fig. 15. Moreover, by using the diamond submount 2, it is possible to quickly diffuse the heat generated in the semiconductor laser element 3 particularly in a wide range including the transverse direction and improve the radiation effect compared to 15 the case of a conventional AlN submount. That is, it is possible to suppress a temperature rise to an injection current compared to the case of a semiconductor laser element set to a conventional semiconductor laser device and realize a high output semiconductor laser device.

Fig. 11 is a graph which shows relations between injection currents and 20 output powers of the semiconductor laser element 3 of this fourth embodiment and a conventional semiconductor laser element. In Fig. 11, the continuous line B shows the characteristic of the semiconductor laser element 3 of this fourth embodiment and the broken line shows the characteristic of the semiconductor laser element 103 of the conventional semiconductor laser device shown in Fig. 15. As shown in Fig. 11, the 25 rate of the output power increasing in accordance with increase of an injection current of the semiconductor laser element 3 of this fourth embodiment is larger than that of the conventional semiconductor laser element 103. Particularly, though a difference is not observed between output powers of the both up to an injection current of approximately 200 mA, the output power of the semiconductor laser element 3 of this 30 fourth embodiment rises up to approximately 440 mW while the output power of the conventional semiconductor laser element 103 is approximately 360 mW at an injection current of approximately 1,500 mA.

The above result that output power increases at the same injection current is caused by the improvement of a power light conversion efficiency due to the above high radiation effect in addition to the fact of controlling the temperature of the semiconductor laser element 3 to a desired value in accordance with a temperature 5 measurement result by the thermistor 4 as described for the first embodiment.

As described above, the structure shown in Fig. 10 makes it possible to carry a current to the p-side electrode of the semiconductor laser element 3 by connecting the metallic thin film 2h on the diamond mount 2 with the metallic thin film 2b on the carrier 1 through a wire. However, it is also possible to form a metallic thin film also 10 on the side face of the diamond submount 2 and provide the function of the wire 5 for the metallic thin film on the side face. The thin film that covers the diamond mount includes Au thin film.

Fig. 12A is a top view, Fig. 12B is a front view, and Fig. 12C is a right side 15 view of another configuration of the fourth embodiment of the present invention. In Figs. 12A to 12C, a portion common to that in Fig. 10 is provided with the same symbol and its description is omitted.

Figs. 12A to 12C are different from Figs. 10A to 10C in that the upper face and side face of the diamond submount 2 are covered with a metallic thin film 2i and wires for connecting the metallic thin films 2h and 2b shown in Fig. 10 each other are excluded. The metallic thin film 2f electrically contacts the p-side electrode of the 20 semiconductor laser element 3 located on the upper face of the diamond submount 2 and the metallic thin film 2b on the carrier 1 to electrically connect the electrode with the metallic thin film 2b.

As described above, the fourth embodiment has all the advantages of the 25 second embodiment. In addition, because the thermistor 4 is set on the carrier 1 without using a submount, production costs and complexity can be reduced compared to the second embodiment.

The fifth embodiment of the present invention is described below. The fifth embodiment uses the semiconductor laser device of any of the above embodiments 30 within a module. Fig. 13 is a sectional view which shows a configuration of the semiconductor laser module that is the fifth embodiment of the present invention. In Fig. 13, the semiconductor laser module 20 has a semiconductor laser device 30

corresponding to the semiconductor laser device described for the above-described third embodiment. As a housing of the semiconductor laser module 20, a Peltier module 28 serving as a temperature controller is set on the inside bottom face of a package 29 made of a copper tungsten alloy or the like. A base 27 is set on the Peltier module 28 and a carrier 34 functioning as a heat sink is set on the base 27.

5 A semiconductor laser element 31, a thermistor 32, and an optical monitor 33 are arranged on the carrier 34 and the semiconductor laser device 30 corresponding to the semiconductor laser device described for the above third embodiment. Moreover, a first lens 22 is set on the base 27. A laser beam emitted from the semiconductor 10 laser element 31 is guided to an optical fiber 25 through the first lens 22, an isolator 23, and a second lens 24. The second lens 24 is set onto the optical fiber 25 on the optical axis of the laser beam and optically coupled with the optical fiber 25 to be externally connected. The optical monitor 33 monitors and detects the light leaked from the reflection film side of the semiconductor laser element 31.

15 In the case of the semiconductor laser module 20, the isolator 23 is set between the semiconductor laser element 22 and the optical fiber 25 so that the return light reflected from other optical component does not reenter a resonator.

20 Though the fifth embodiment use a semiconductor laser module for directly outputting a laser beam output from the semiconductor laser element 31, it can be also applied to an optical fiber grating semiconductor laser module for wavelength selecting and outputting a laser beam output from the semiconductor laser element 31 by forming the optical fiber grating near by an end of the second lens 5 of the optical fiber 25. In this case, the isolator 23 is not used.

25 In the case of this fifth embodiment, because the semiconductor laser device uses a semiconductor laser module mounting a high output semiconductor laser element and constitutes a semiconductor laser device having the same configuration as the third embodiment, it is possible to quickly and accurately perform the temperature control of the semiconductor laser element and resultantly realize a semiconductor laser module reduced in size and weight. Moreover, even if the carrier 34 serving as a 30 heat sink is increased in size in accordance with improvement of the semiconductor laser element 31 in output, it is possible to suppress the deterioration of a power light conversion efficiency.

Though the above fifth embodiment is formed into a module by using the semiconductor laser device described for the third embodiment, it is naturally possible to replace the semiconductor laser device 30 shown in Fig. 13 with the semiconductor laser device having the configuration described for each of the first, second and fourth embodiments.

Then, a result of comparing the output power of the conventional semiconductor laser device shown in Fig. 15 with the output power of each of the semiconductor laser devices described for the first and fourth embodiments is described below. is a graph which show the comparison between peak values of output powers of a conventional semiconductor laser device and the semiconductor laser device described for each of the first and fourth embodiments. On the abscissa axis shown in Fig. 14, A corresponds to the semiconductor laser device of the first embodiment (Fig. 1) and B corresponds to the semiconductor laser device of the fourth embodiment (Fig. 12).

15 As shown in Fig. 14, an output power larger than that of the conventional semiconductor laser device is obtained from each of the semiconductor laser devices (A and B) shown for the first and fourth embodiments. Moreover, as a result of comparing output powers between the semiconductor laser devices shown for the first and fourth embodiments, a largest output power of approximately 377 mW is obtained
20 from the semiconductor laser device (B) having a structure in which only the thermistor 4 is set on the carrier 1 and the semiconductor laser element 3 is set on the diamond submount 2 and then, an output power of approximately 370 mW is obtained from the semiconductor laser device (A) in which the semiconductor laser element 3 is set on the carrier 1.

25 From these results, it is found that the diamond submount 2 has a very large
radiation effect because a large output power is obtained from a structure (B)
constituted by adding the diamond submount 2 on which the semiconductor laser
element 3 is set to a structure (A) having the shortest heat conducting path compared
to the case of the structure (A).

30 In the case of the above first and fourth embodiments, a submount set immediately below the semiconductor laser element 3 is formed by diamond. However, it is preferable to actually use the diamond having a high heat conductivity

of 1,000 to 1,300 W/(m · K). Moreover, it is possible to obtain the above advantage even if using a material {500 W/(m · K) or more} having a heat conductivity higher than that of AlN such as BN of 600 W/(m · K) or more other than diamond.

As described above, according to the first aspect of the invention, a semiconductor laser element for outputting a laser beam and a temperature measuring element for measuring the temperature of the semiconductor laser element are arranged on the same carrier having an advantageous insulating characteristic and a high heat conductivity and the semiconductor laser element and the temperature measuring element are joined to the carrier through a specially configured multi-layer film that includes a gold thin film so as to decrease the heat resistance of a heat conducting path including proximity arrangement. Therefore, advantages are obtained that the temperature measuring element can more accurately and quickly detects the temperature of the semiconductor laser element and prevent the optical output and service life of the semiconductor laser element from deteriorating. And because the carrier is formed by any one of Si, AlN, diamond, and cBN polycrystal, or a combination of them, an advantage is obtained that it is possible to flexibly select a material of the carrier.

According to the second and fourth aspects of the invention, a semiconductor laser element for outputting a laser beam is joined to a submount formed by a heat sink joined to a carrier and having a heat conductivity of 500 W/(m · K) or more through a multi-layer film including a gold thin film, and a temperature measuring element for measuring the temperature of the semiconductor laser element is joined, either via the same submount or directly, to the same carrier having an insulating characteristic and a high heat conductivity through a specially configured multi-layer film that includes a gold thin film so as to decrease the heat resistance of a heat conducting path including proximity arrangement. Therefore, advantages are obtained that the temperature measuring element can more accurately and quickly detect the temperature of the semiconductor laser element and prevent the optical output and service life of the semiconductor laser element from deteriorating. And because diamond has a high heat conductivity and it can be set on a lower layer of the semiconductor laser element to further accelerate the reduction of the heat resistance and the improvement of the radiation effect of a heat conducting path, thus advantages

obtained include the fact that a temperature measuring element can more accurately and quickly detect the temperature of the semiconductor laser element and prevent the optical output and service life of the semiconductor laser element from deteriorating.

An advantage unique to the fourth aspect of the invention in the restriction of
5 use of the submount to just semiconductor laser element is a reduction in production
costs.

According to the third aspect of the invention, because a monitor element for monitoring the output of a laser beam output by a semiconductor laser element is also set on the carrier via a specially configured multi-layer film, an advantage is obtained
10 that it is possible to further accelerate the decrease of a semiconductor laser device in size and weight. And because at least one of the semiconductor laser element, temperature measuring element, and monitor element is made electrically independent, an advantage is obtained that it is possible to further accelerate the decrease of a semiconductor laser device in size and weight.

15 In aspects one through four of the invention, because the semiconductor laser element and the temperature measuring element electrically join one electrode with the above conductor pattern by conductive wires and decrease lengths and the density of the wires, an advantage is obtained that it is possible to decrease the semiconductor laser device in size and weight. And because a plurality of the conductive wires are used, the conductive wires can be joined each other at almost equal intervals on the semiconductor laser element, and the temperature measuring element, and/or the above conductor pattern to uniform voltage drops to the semiconductor laser element and minimize voltage drops and heat generation due to the conductive wires, advantages are obtained that it is possible to prevent the optical output and service life of the semiconductor laser element from deteriorating, reduce the total heat generation of a semiconductor laser device, and improve the power light conversion efficiency of the semiconductor laser device.

Also in aspects one through four, the thickness of the gold thin film is set to 5 μm or more so that the heat resistance between a semiconductor laser element and a temperature measuring element decreases and moreover, the voltage drop of the above conductor pattern is suppressed, advantages are obtained that the temperature measuring element can quickly and accurately detect the temperature of the

semiconductor laser element, resultantly the temperature measuring element can quickly and accurately perform the temperature control of the semiconductor laser element and improve a power light conversion efficiency due to reduction of the voltage drop of the conductor pattern. These advantages are possible even for a high 5 output semiconductor laser element has resonator length of 1,000 μm or more.

Also in aspects one through four, because the active layer side of the semiconductor laser element is joined to the carrier, the active layer for generating much heat is made to approach a carrier and a submount at a lower layer, heat sink functions of them are maximally shown, and temperature measurement is perform at a 10 high accuracy by a temperature measuring element, advantages are obtained that it is possible to prevent the optical output of the semiconductor laser element from deteriorating and improve the reliability, particularly the service life of the semiconductor laser element. Also, because the temperature control of the semiconductor laser element can be quickly and accurately performed even if the 15 output of a laser beam output from the semiconductor laser element is set to a high output of 250 mW or more, an advantage is obtained that it is possible to prevent the optical output from deteriorating even for a high output semiconductor laser element.

According to the fifth aspect of the invention, because the carrier of a semiconductor laser device is joined to a temperature controlling element such as a 20 Peltier module, a semiconductor laser element and a temperature measuring element are arranged on the carrier, the semiconductor laser element is temperature controlled in accordance with the temperature measured by the temperature measuring element, an advantage is obtained that it is possible to realize a semiconductor laser module capable of preventing the optical output and service life from deteriorating even when 25 the semiconductor laser element has a high output. And because the heat resistance of the heat conducting path between the semiconductor laser element and the temperature controlling element is decreased by decreasing the number of junction faces located on the heat conducting path and respectively formed by a multi-layer film including a gold thin film to four or less, an advantage is obtained that it is 30 possible to accurately and quickly control temperature by the temperature controlling element.

In this application, we describe embodiments using only n type substrate. But

p type substrate is adapted to this invention.

5 Although the invention has been described with respect to a specific embodiment for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art which fairly fall within the basic teaching herein set forth.

This document claims the benefit of the earlier filing dates of Japanese patent applications 2001-059325 and 2001-319847 filed in the Japanese Patent Office on 03/02/2001 and 10/17/2001 respectively, and the entire contents of both of these Japanese patent applications being incorporated herein by reference.